SYNOPSIS

URBAN GROWTH MAPPING, ANALYSIS AND PREDICTION USING TECHNIQUES OF REMOTE SENSING, GIS AND SPATIAL MODELING IN THE MEDIUM-SIZED CITY OF MANGALURU, INDIA"

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(Department of Geography)

S Y N O P S I S

of the Ph.D. thesis entitled

"URBAN GROWTH MAPPING, ANALYSIS AND PREDICTION USING TECHNIQUES OF REMOTE SENSING, GIS AND SPATIAL MODELING IN THE MEDIUM-SIZED CITY OF MANGALURU, INDIA"

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by

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December, 2021

SYNOPSIS

Tittle of the thesis	:	"Urban Growth Mapping, Analysis and Prediction Using Techniques of Remote sensing, GIS and Spatial Modeling in the Medium-sized City of Mangaluru, India"
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DECLARATION

I hereby declare that the synopsis entitled "**URBAN GROWTH MAPPING, ANALYSIS AND PREDICTION USING TECHNIQUES OF REMOTE SENSING, GIS AND SPATIAL MODELING IN THE MEDIUM-SIZED CITY OF MANGALURU, INDIA**" to be submitted for the award of Degree of Doctor of Philosophy of Mangalore University is my original work and the synopsis has not formed the basis for the award of any degree, diploma, or fellowship of similar other titles to any other University or Institution.

Place: Mangalagangothri
Date: 22/12/2021

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INTRODUCTION

Cities have always been a centre of human fascination; it is among the most intricate things ever created by human beings. Cities have always been the heart of civilization throughout the history of mankind, making humans settle down in a large group on a relatively small portion of the earth surface. The captivation of humanity towards cities has only grown today with more than 50% (55.71% in 2019 according to the United Nations) of the world's total population residing in cities across the world (World Bank, 2019). The proportion of people residing in urban areas is expected to grow even further to 68% by the year 2050 (United Nations, 2018). Today, urbanisation and urban growth are taking place in the developing part of the world; unlike the western cities, the cities in the developing world have a whole new set of challenges and opportunity.

Urbanization has grown to such an extent today that from 1950 to 2020 alone population residing in urban areas grew by more than six-fold from 751 million to 4.4 billion, which is unparalleled in the history of the world. The number of countries getting urbanised has also been increasing suggestive of global coverage of the phenomenon. Technological advancements and industrial revolutions have enabled rapid urban expansion around the world. Industrial production and job concentration has attracted people from villages to settle in cities and has fundamentally changed the morphology and environment of the cities and people's lifestyles (Arbury, 2005); (Gu, 2019).

Urbanisation worldwide in recent decades is increasingly becoming a characteristic feature of developing countries (Dwyer, 1979; World Bank, 2020). Globally the trends and patterns of urbanisation were regionally influenced, and this has been historically proven true. Countries of Europe and North America saw increased growth of urbanisation in the 19th and early 20th centuries (Burdett, 2015). Currently, an exponential growth rate of urbanisation is likely to occur in the countries of Asia and Africa (United Nations, 2018). In India, the rates of urbanisation were initially sluggish, and then later the growth rate picked up steadily from 11.4% in 1901 to 31.16% in 2011(Mohan &Dasgupta, 2004; Census of India, 2011; Census of India,

2001; Bhatt &Jani, 2018). The economic liberalization and large-scale investments in the early 1990s have incited a rapid increase in the share of the urban population in India. According to the United Nations report on world urbanisation; India is predicted to add 404 million, more urban dwellers by 2050. Even more importantly, these growths are going to take place in cities of less than one million populations (United Nations, 2018). This brings the small and medium-sized cities to the canvas of Indian urbanisation, the urbanisation of future India.

The projected increase in the urban population of India in small and medium-sized cities brings in a huge opportunity in the urban development of the country. This sets up the right juncture for action in innumerable small cities of India (Swerts, 2017; Denis, Mukhopadhyay, & Zérah, 2012). In the present thesis, an attempt was made to study the urban growth dynamics from the perspective of past, present and future in the medium-sized city of Mangaluru using geospatial techniques and thus provide a context to the contemporary nature of urbanisation in the country.

Scope of the study

In the background of rapid urban growth in the country and particularly the small and medium-sized cities, the current study on the city of Mangaluru and the surrounding urban region has greater present and future implications. Realising the urban growth potentials of small and medium-sized cities, the time has arrived to focus equally on small and medium-size cities of India.

The findings of the present study would be helpful for policymakers in creating a sustainable and participatory urban policy framework for medium-sized cities like Mangaluru. Lack of spatial data and land use information at a smaller scale often hampers the task in developing countries in general. One of the prerequisites for sustainable city planning is therefore the availability of geospatial data of land use and land cover and urban growth to assist in formulating strategies (Roy &Giriraj, 2008). The use of open-source geospatial data has been demonstrated in the present study in understanding the urban growth dynamics of small and medium-sized cities. Studies on the historical evolution of cities using geospatial techniques have not been undertaken on any of the Indian cities so far. The current study attempts to trace the urban history of Mangalore city, which would be helpful to understand the multi-layered urban settlement canvas and the history of the evolution of the city.

Research problem

Urban growth studies of small and medium-sized cities are rarely undertaken. In the context of the projected growth of the urban population of India in the small and medium-sized cities, there is a need to understand the dynamics of urban growth for sustainable urban management. Lack of data for mapping and managing urban growth must be overcome through designing an efficient and cost-effective approach. Similarly, studies on the historical patterns of evolution of urban settlements need to be undertaken given its importance in spatial and urban planning. The absence of spatial data of ancient times is also a challenging task that needs to be addressed. There exists a knowledge gap with respect to the utilisation and development of a methodology to understand the historical urban growth process and choosing a suitable urban growth model to predict urban growth in the emergent city and develop analysis methods.

OBJECTIVES

The major objectives of the study are listed below;

(i) Mapping the historical evolution of urban settlements in Mangaluru city from 7^{th} C. to 20^{th} C.

(ii) To analyse Land Use and Land Cover (LULC) changing status, transition and to observe urban growth in Mangaluru and surrounding areas.

(iii) To quantify urban expansion dynamics and spatial patterns for sustainable land-use planning.

(iv) To analyse the nature of contemporary urbanisation in the context of the emergence of Census Towns (CTs) and rapid rural-urban transition.

(v) To model urban growth and simulate future urban growth scenarios in Mangaluru and surrounding areas in the CA-based SLEUTH model.

(vi) Recommending the measures of urban growth management to achieve sustainable development goals.

STUDY AREA

The city of Mangaluru lies on the coastal plains of south-western Karnataka, slightly west of the rolling hills of the Western Ghats. Administratively the city is situated within the Mangalore taluk of Dakshina Kannada district in the southern Indian state of Karnataka (Figure 1). The city is well connected by networks of roads, railways, and the airport and seaport. The presence of National Highway NH-16, NH-66, and NH-73 in Mangalore ensures easy connectivity of the city with the rest of the country. Apart from the geographical distinctiveness of the place, the region is known for its unique culture, language and traditions of its own. Mangalore was an important city of the erstwhile Tulu Kingdom (Bhatt, 1969). The region has been historically an agricultural society known for its trade relations across the Arabian Sea in Africa, the gulf and the far south-east (Benjamin, 2017). The city is known as the cradle of the Indian banking sector and also an educational hub in the region.

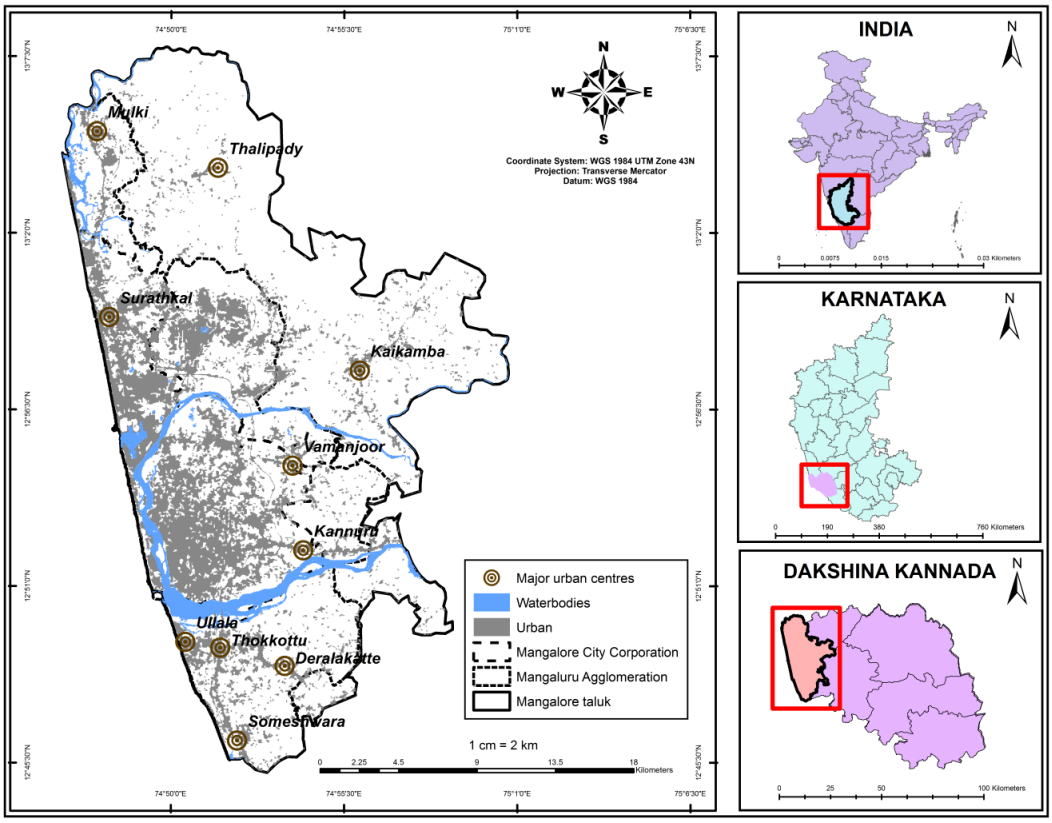


Figure 1 Location map of the study area

The city of Mangaluru has emerged as an industrial sprout in the country facilitated by a well-connected seaport enabling easy transport of goods and raw materials. Besides the health care industry and educational sector is booming in the city. The rapid population growth and a corresponding increase in urbanisation are manifest in the city, giving scope for real estate development in the city. The large-scale developmental activities due to industrial development and also the tertiary sector in Mangaluru have made the city a prospective metropolis in the region. The city is also been given Special Economic Zone status by the Government of India, to further support growth in the region. In the current study, the study area includes the Mangaluru urban agglomeration and further the administrative boundary of Mangalore taluk has also been considered expecting future urban growth beyond the city limits.

METHODOLOGY

The methodology consists of data collection, data processing and analysis. The present study requires data from both spatial and non-spatial types. The spatial data mainly consists of satellite imageries, GPS location points, Google earth imageries, SRTM DEM, topographic sheets of the Survey of India in 1:50K scale shapefiles, transport networks and other ancillary maps etc. The non-spatial data such as census data from Census of India, other relevant socio-economic data, government publications, reports etc. are also used in the study. The study was conducted using a wide range of software and computer codes such as *ArcGIS, ERDAS IMAGINE, QGIS, Google Earth, Microsoft Excel, XL Toolbox NG* extension, *XLSTATS* extension, SAS Planet, *Fragstats, Cygwin, and SLEUTH* codes etc.

The analysis of the study can be generally put under three sections as (i) data exploration-image classification and urban area extraction, (ii) quantifications and analysis of urban growth and (iii) calibrations of the model and prediction of urban growth based on the study objectives. In the first section, the status of urban growth during the past and the present period has been extracted using methods of remote sensing, GIS and spatial statistics. In the second section, the extracted urban patches of multiple dates were used in further analysis of the urban growth dynamics in Mangalore. A range of spatial metrics such as Shannon's sprawl index, urban expansion

indices, land-use patch metrics and goodness of urban growth indices were calculated to understand the nature of urban growth and sprawl in the study area. An analysis of contemporary urbanisation taking place in Mangalore is also analysed using statistical methods to suggest sustainable land-use planning and smart growth. Finally, in the third section, the historical urban growth layers extracted from the satellite imageries were used to calibrate the CA-based SLEUTH urban growth model and then to predict the future urban growth of Mangalore in 2031.

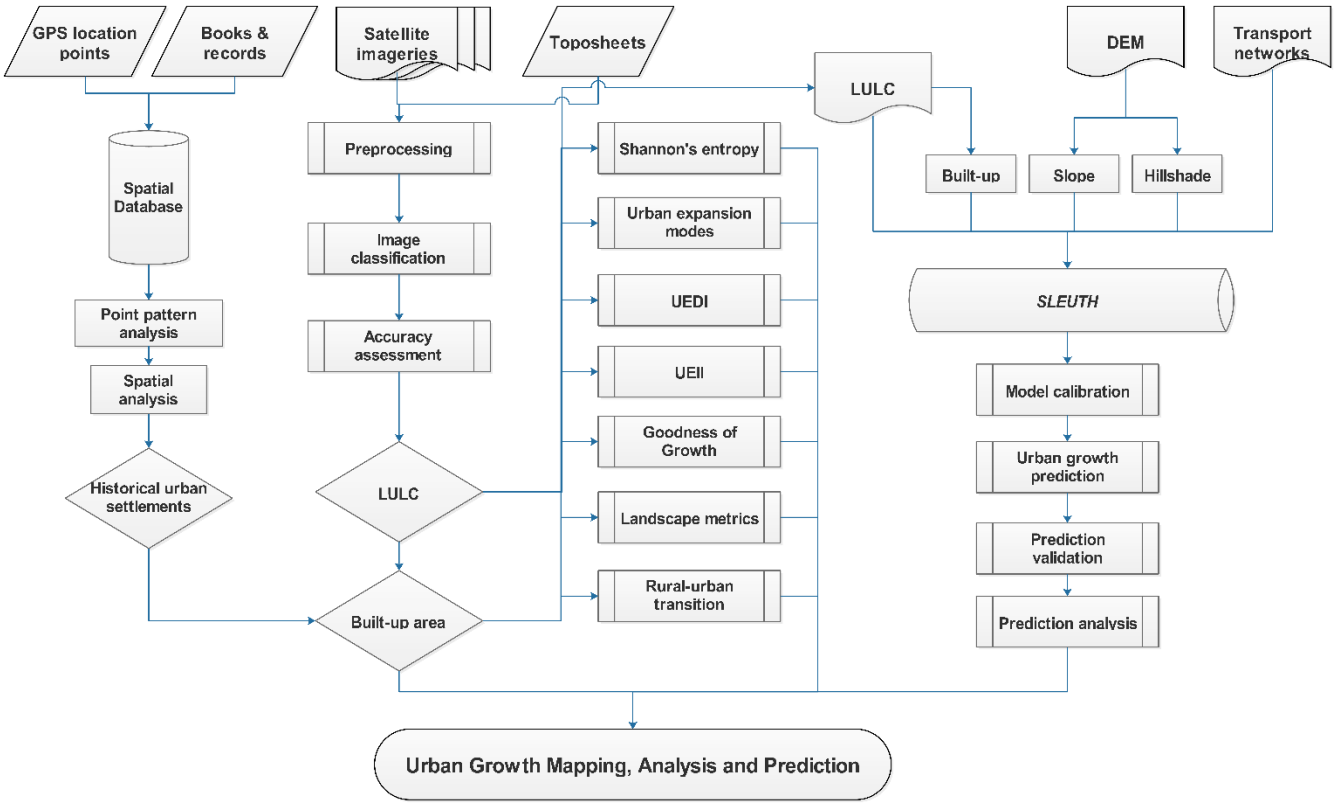


Figure 2 Methodology flow chart of the present study

ORGANISATION OF THE THESIS

The thesis is organised into 9 main chapters and can be broadly divided into two sections. The first part consisting of chapters 1 to chapter 3 deals with the introductory aspects of the study including background, concepts and the location of the study. The second part covers chapter 4 to chapter 9 deliberates upon the primary objectives of the study comprehensively. The main chapters (chapters 4 to 8) have been designed to comprehensively address each above-mentioned research objective by constructing a methodological framework and analysis to fit the data and finally to derive the results. Lastly, chapter 9 discusses the major findings, conclusions and recommendations of the study.

Chapter 1: Introduction

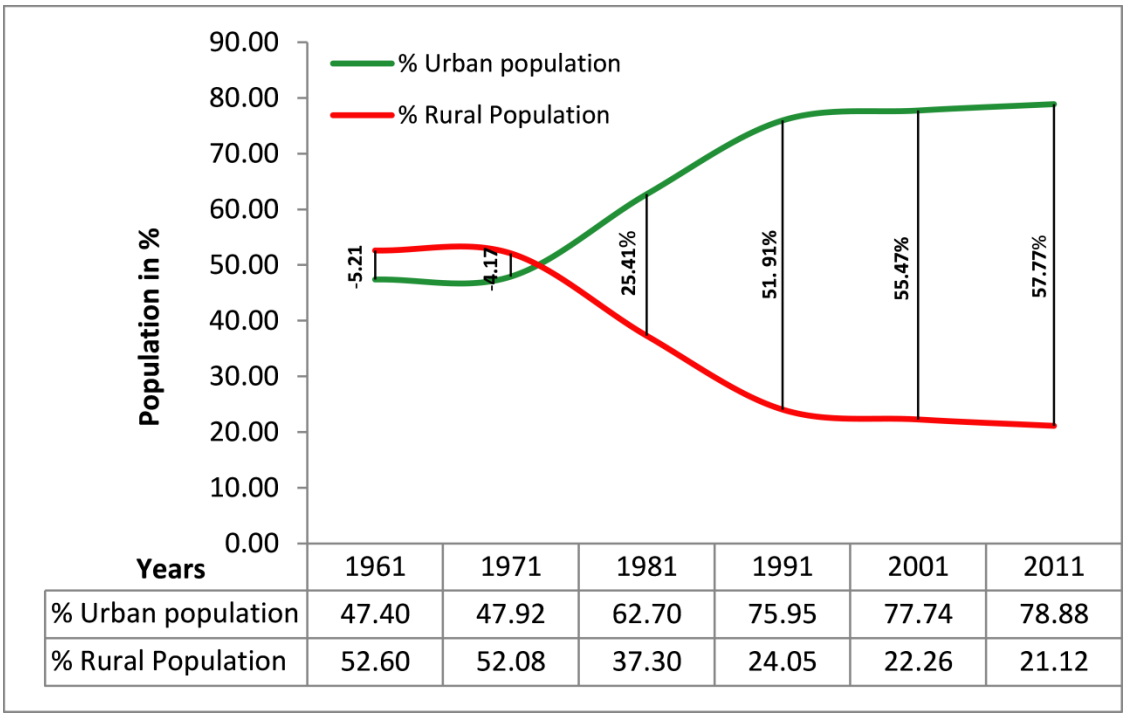
The chapter provides, a background to the thesis in which discussions on the urbanization process starting from the general history of urbanisation to its contemporary development put into perspective the fundamental arguments of the thesis. The chapter similarly presents an overview of the major theoretical concepts underlying the thesis in great detail by associating them with the objectives of the study. The chapter also provides the statement of the research problem, motivation, justification, the scope, objectives and research questions, research design and methodological outline of the study.

Chapter 2: Literature Review

The chapter presents a literature review covering the major objectives of the current study. The literature review is organized according to the order of the objectives stated in the study. The review has been done covering the relevant topics such as Historical GIS, urban sprawl, LULC and urban growth monitoring through remote sensing, urban growth quantification, spatial metrics, urban growth modeling techniques particularly using cellular automata based urban growth models, and SLEUTH urban growth model etc. The literature review provides a validation of the research objectives, research question and methodology through literature gathered from the core academic discussions covering regional, national, and global scale in a definite chronology.

Chapter 3: Study area

It provides an overview of the study area. A brief history of Mangaluru covering the culture, traditions and language of the region and a discussion on the administrative history of the region starting from early rulers to the colonial era and post-independence period was also provided. Besides, the chapter includes deliberations on the geographical location, physiography, lithology, climatic settings, flora and fauna, demography, economy, transportation, education, health sector, tourism industry etc. and therefore provides a context for the further chapters in the thesis. Figure 3 shows the general trend of percentage urban and rural population growth in the study area since the year 1961 to 2011.



Years	1961	1971	1981	1991	2001	2011
% Urban population	47.40	47.92	62.70	75.95	77.74	78.88
% Rural Population	52.60	52.08	37.30	24.05	22.26	21.12

Figure 3 Percentage of the urban and rural population in the study area since the year 1961

Chapter 4: Historical Evolution of Urban Settlements

It deals with the mapping historical evolution of urban settlements in Mangaluru using Historical GIS and different spatial analysis techniques. The method uses GPS locational points of historical structures, buildings, temples etc. from A. D. 600 to 1970 to interpret the historical spatial extent, pattern of spatial arrangement and the evolution of urban settlements. The chapter provides a reconstruction of the urban process in Mangaluru and demonstrates the reusability of the method in the handling and analysis of spatial data and provides a new avenue of research. The major findings of chapter 4 are;

- Constant fluctuations of the mean centre of settlements during 600-1970 A.D. suggests the dynamic nature of the socio-economic, religious and political scenario of Mangalore
- The standard deviational ellipse constructed for different periods based on the locations of historical buildings, structures, etc. helps to visualise directional deviation and morphology of settlement. The unevenly distributed settlements during 600 A.D. started to evolve into a circular form suggesting the evolution of a city centre particularly with the arrival of Portuguese by 1500 A.D.
- Nearest neighbour analysis and Kernel density estimate (KDE) shows the decreasing distance between settlements and intensive growth with time. The approximation of the urban settlement boundary was done through variable buffer analysis for visual analysis (Figure 4).

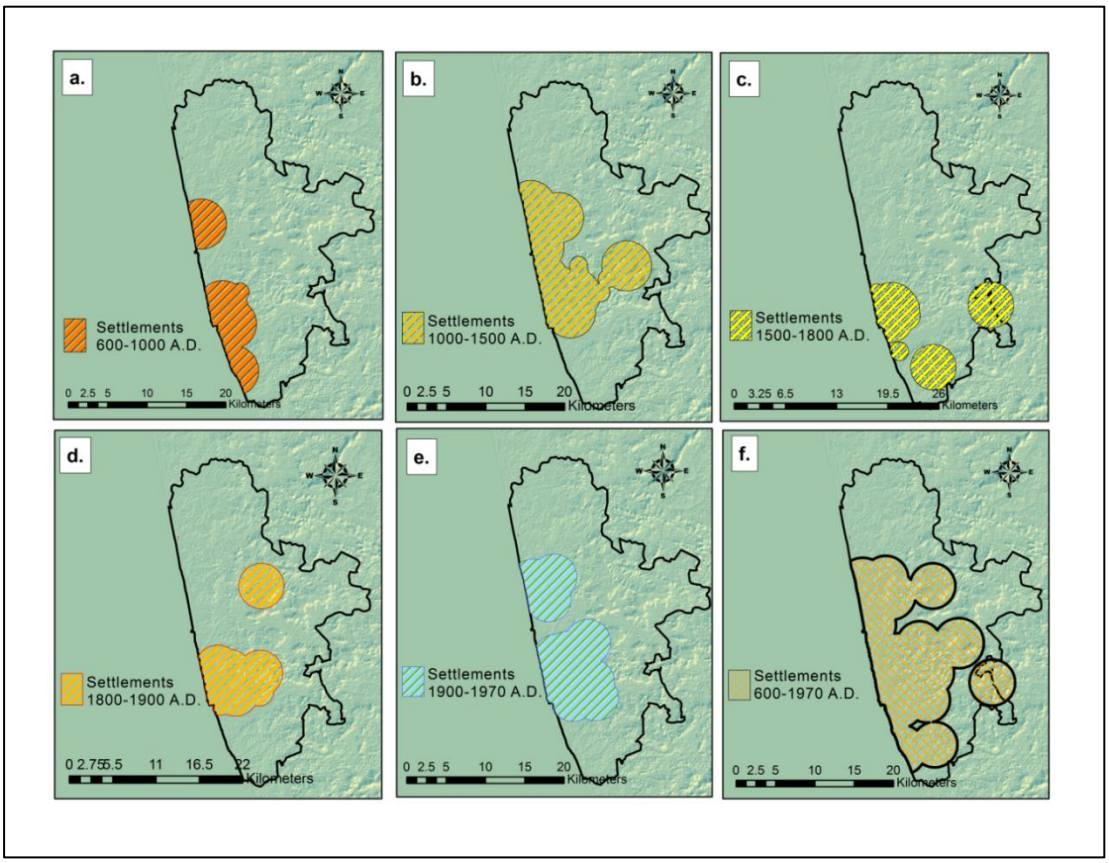


Figure 4 The variable buffer area for the locations of historical buildings and structures of Mangalore from a. 600 to 1000, b. 1001 to 1500, c. 1501 to 1800, d. 1801 to 1900, e. 1901 to 1970, and f. 600 to 1970

Chapter 5: Land use land cover mapping and monitoring urban growth

Presents land use land cover mapping and urban growth monitoring using remote sensing and GIS techniques employing MLC classification, transition matrix, Shannon's entropy and spatial trend approaches. The study uses the Landsat data for the 1972-2018 periods and provides evidence of land use land cover change dynamics and increased built-up growth. The chapter puts into perspective, the proposition of, the latent ability of Mangaluru city to grow as one of the major cities on the western coast of India. The outcomes of chapter 5 are listed below;

- During the period from 1972 to 2018 LULC area in Mangaluru has experienced drastic fluctuations mainly induced by urban growth in the region (Figure 5 & Table 1). The agricultural and open land has drastically reduced whereas vegetation and built-up land has increased, while there was only a marginal decrease in water bodies' category in the study area.
- The urban area has increased from 2100 Ha in 1972 to 10616 Ha by 2018, an increase of more than 400% during the period (Table 2).

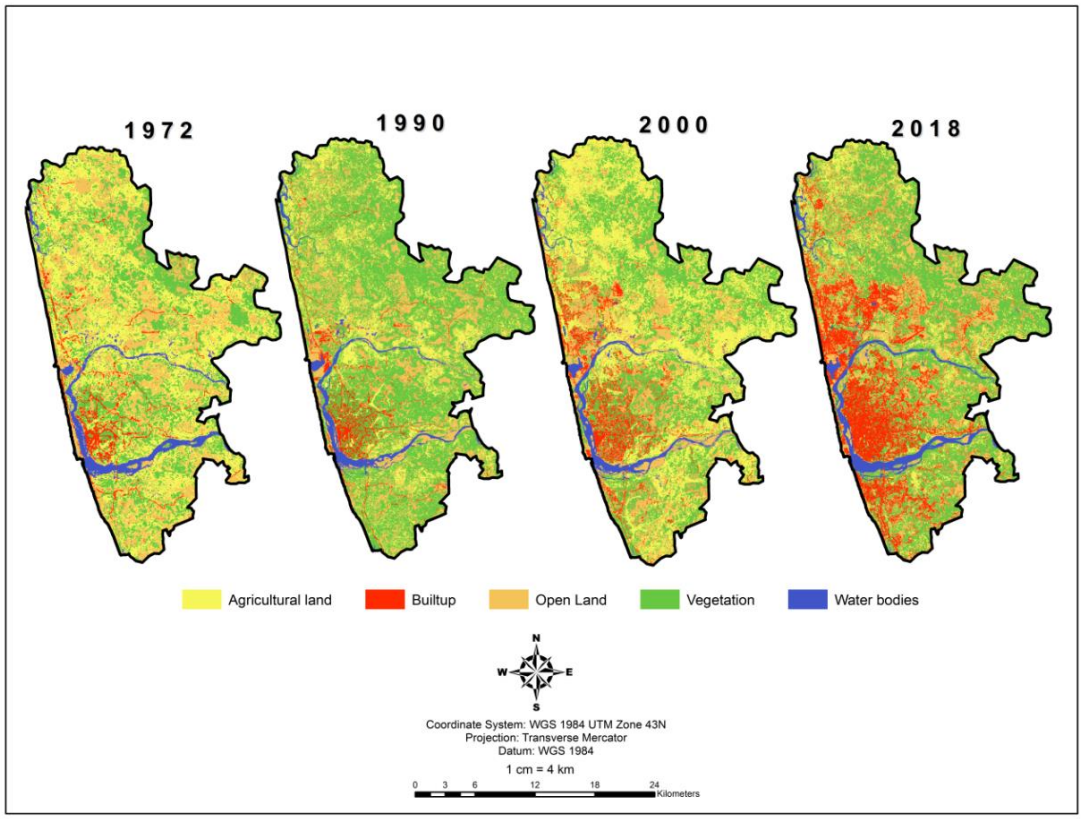


Figure 5 Land use land cover map of the study area for the years 1972, 1990, 2000 and 2018

- The transition of land cover types to built-up area shows that the larger part of vegetation land was converted to built-up land which is followed by open, agricultural and water bodies.
- The overall urban growth form in the study area was found to be compact through Shannon's entropy analysis, which is due to the concentration of built-up mostly in the downtown area and along the coastal tracts. However, an increasing trend in entropy value in the year 2018 is an exemplification of the growth that has occurred mainly to the north and south of the city along the highways.
- The spatial trend of built-up change through trend surface interpolation result shows a steady trend in the insurgence of built-up area, characterised by a recent trend of intensive growth in the north and south of the city.

Table 1 Land Use Land Cover classification scheme used in the study

No	LULC Classes	Description
1	Built-up	Residential, industrial, commercial, transport network
2	Agricultural Land	Crop Land, Pre-sow, Post-Sow
3	Vegetation	Forest, Natural vegetation, Planation, Shrub, Grass
4	Water bodies	River, Pond, Wetland, Sea
5	Open Land	River sand, beach, rocky outcrop, hills, Wasteland, Open ground

Table 2 Area of land use and land cover classes and Change Statistics from 1972-2018

Classes	Area in Hectares				Dynamic Degree (%)				Change of Area
	1972	1990	2000	2018	(1972-1990)	(1990-2000)	(2000-2018)	(1972-2018)	
Agricultural land	20791	10584	19715	6337	-2.73	8.63	-3.77	-1.51	-14453.81
Open land	14845	12021	11405	14407	-1.06	-0.51	1.46	-0.06	-437.64
Water bodies	3044	2285	2183	2856	-1.38	-0.45	1.71	-0.13	-187.59
Vegetation	16170	29345	19169	22255	4.53	-3.47	0.89	0.82	6084.52
Built-up	2100	2525	4288	10616	1.12	6.98	8.20	8.81	8515.57

Chapter 6: Quantification of urban expansion dynamics and spatial patterns for sustainable land-use planning

The chapter deals with the quantification of Spatio-temporal urban expansion dynamics, intensities and its spatial pattern using spatial metrics. The analysis derives urban expansion types and the spatial arrangement and configuration of built-up patches in the study area. The Fragstats derived spatial metrics in the chapter was found to be effective indicators of the socio-economic status of the settlements as well. The chapter also proposes the goodness of urban growth index for sustainable land-land use policy in the city. The highlights from the findings of the study are listed below;

- Extraction and analysis of urban expansion modes namely; infilling, edge growth and leapfrogging have revealed the relative dominance of leapfrog and edge growth over infill urban expansion mode (Figure 6). The development, in general, indicates the sprawling propensity of Mangaluru city with time.
- The overall UEII for each period was seen increasing from 0.04 in 1972-1990, 0.35 in 1990-2000 and 0.62 in 2000-2018 periods. Though the overall speed of urban expansion was medium, the urban expansion rate has almost doubled in each period, indicating rapid urban growth in the region.
- The UEDI scores of all directions show the urban expansion was quicker initially in most of the zones, which in later periods become intense at selective zones, influenced by certain growth controlling factors.
- The goodness or badness of urban growth is measured using the degree of goodness index suggest that the urban growth in the study area was highly unsustainable owing to poor urban planning (Table 3).
- Using standard landscape metrics, the spatial characteristics of urban patches were analysed. The characterisation of built-up patch dynamics through area-edge, shape, aggregation, sub-division and isolation metrics shows more distributed urban growth in Mangaluru linked with increasing transportation connectivity pattern across the study area, rural-urban transition, shape metrics reflecting lack of efficient urban planning etc. It was also found that the changing built-up spatial metrics can be indirectly linked to the socio-economic status of settlements in the region as well.

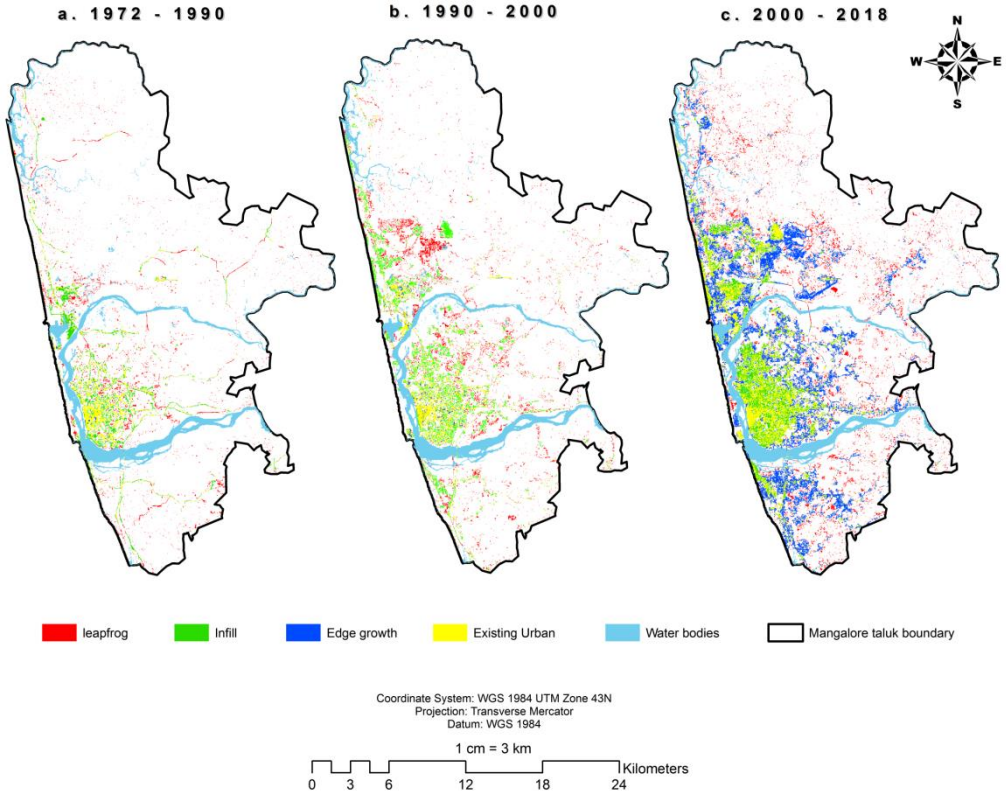


Figure 6 Modes of urban expansion in Mangaluru during 1972-1990, 1990-2000 and 2000-2018

Table 3 Overall degree of freedom, sprawl and goodness of urban growth in Mangaluru

Degree of freedom	Sprawl	Degree of goodness
463.11	2.78	-6.01

Chapter 7: A geospatial analysis of the nature of contemporary urbanization in Mangaluru

It provides an analysis of the contemporary nature of urbanization in Mangaluru in the backdrop of rapid rural-urban transition and increasing Census Towns (CTs). The chapter demonstrates the correlation between the emergence of new CTs, rural-urban transition and proximity with the STs and transportation network through spatial and locational analysis. The chapter also presents the increasing peripheral rural-urban transition of the city using multiple spatial analysis techniques. The key findings of chapter 7 are;

- The study identifies the rapidly changing urban dynamics of CTs over STs in the region and their role in the rapid evolution of the city of Mangaluru. It has

been established from the study that CTs are better than or as same as the STs in terms of population growth rate, economic activities and other social indicators.

- The correlation between the emergence of CTs or rural-urban transition and proximity to STs and transportation networks has been identified in the study area.
- The density-based demarcation of the urban area and Kernel density estimate establishes the rapid rural-urban transition particularly in the periphery of the city. The value of LCR and LAC contrasted between urban core area and periphery also points towards active urban transition in areas away from the city.
- The spatial metric used to recognize the dynamics of settlements in the periphery of the city confirms the emergence of new urban centres in the rural hinterland.
- The environmental impact of rural-urban transition and in-situ urbanization analysed through land surface temperature also reveals the increased effect of built-up expansion and urbanization particularly in the periphery of the city on the environment is pronounced.

Chapter 8: Urban growth simulations through Cellular Automata-based SLEUTH urban growth model

The chapter presents a cellular automata-based SLEUTH urban growth model to simulate urban growth in Mangaluru for the year 2031. The model uses slope, land use, exclusion, urban, transportation, and hillside of the study area as input to simulate urban growth from the base year 2016. In addition, the model calibration, description of input data, validation of predicted results is also provided in detail. The predicted urban growth in Mangaluru, its spatial pattern, trend and its implications for sustainable urban growth and regional planning are discussed. The chapter also highlights some of the limitations of the SLEUTH model in predicting the urban growth of a medium-sized city like Mangaluru. The important results derived from the study in chapter 8 are;

- There would be an expected increase of 6895 Ha of urban area in Mangaluru during the 2020 to 2031 period.

- The SLEUTH model has found that slope resistance, spread and road gravity are the major controlling growth types in Mangaluru.
- The new predicted urban growth is expected to occur along the highways and the current urban patches would spatially expand due to edge growth.
- Spatially the growth is anticipated to take place particularly in the northern and southern part of the city along the national highway. The southern part of the city would grow to become an important hub for the service sector in the city.
- Besides, infill and edge growth will make the existing urban areas densely packed particularly in the core urban area.
- The analysis of the spatial pattern of the urban area through spatial metrics suggests that the urban growth in the study area is increasingly becoming aggregated and also indicates the emergence of multiple growth centres away from the core of the city.

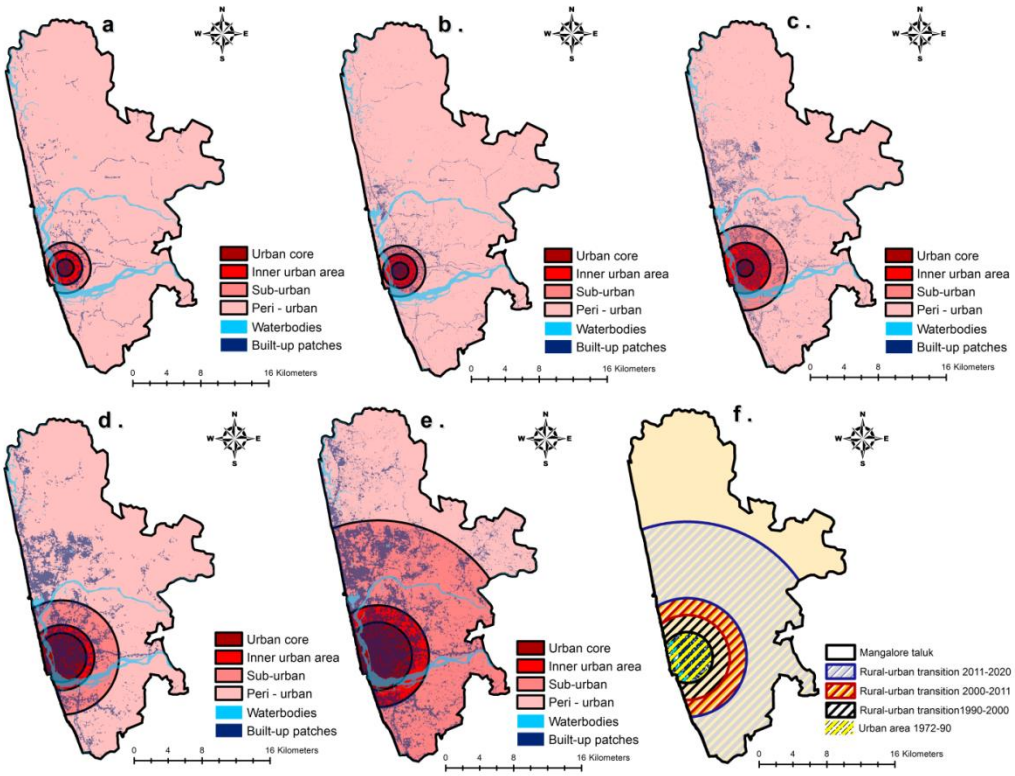


Figure 7 Urban form demarcation as the urban core, inner core, sub-urban and fringe or peri-urban based on density in the study area for the year a. 1972, b. 1990, c. 2000, d. 2011, d. 2020 and f. showing rural-urban transition during 1972-2020.

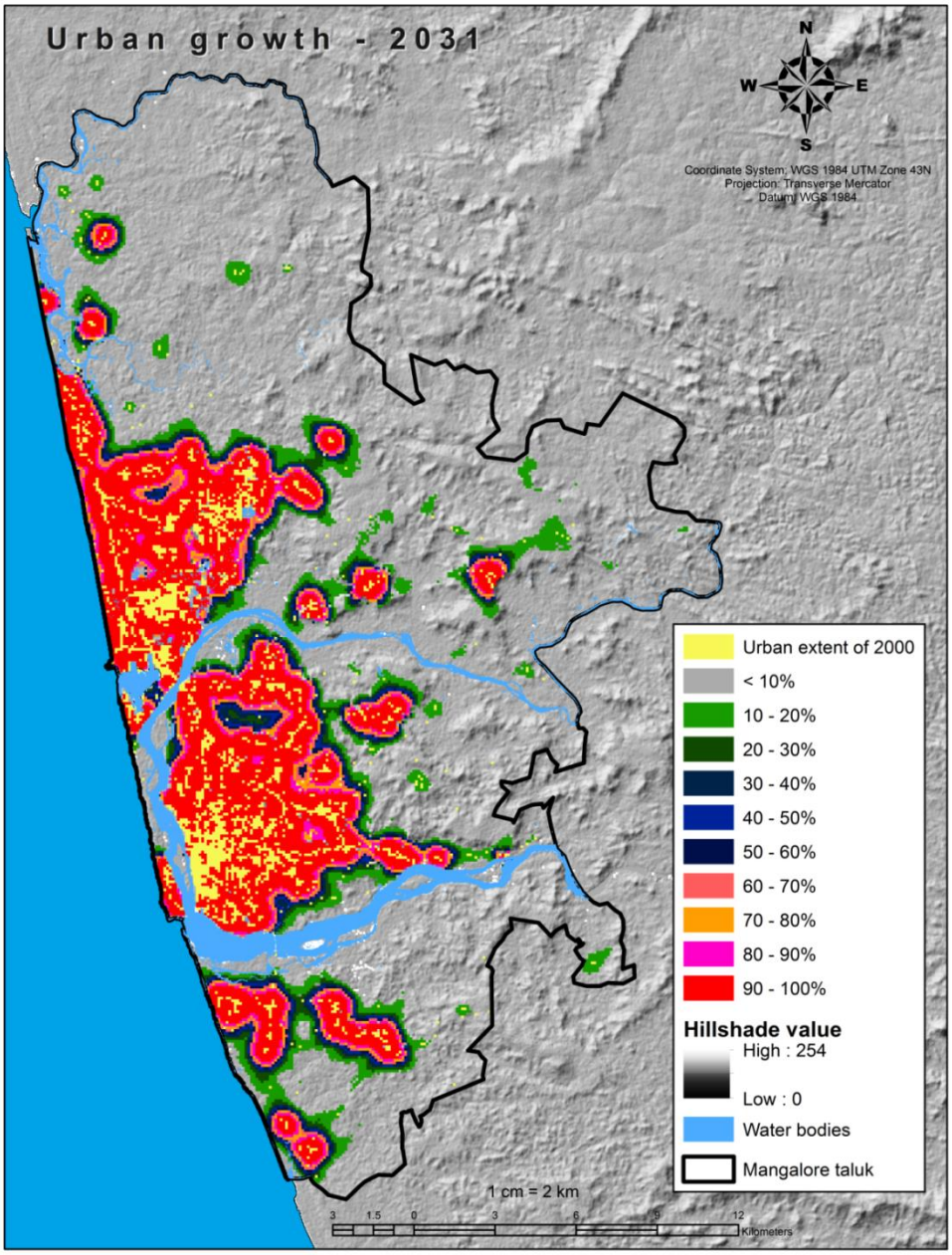


Figure 8 Predicted urban growth of Mangaluru for the year 2031 in different proportions

Chapter 9: Conclusion

The chapter provides a conclusion to the study by including major findings, the aspects of novelty, and critical reflections of the study. The chapter also offers recommendations based on the findings of the study for an improved spatial planning and urban governance framework foreseeing the urban growth potential of the city, and

also suggests prospective future work or an extension to the present work. Major findings of the study are;

1. The spatial statistical tools and spatial approximation techniques of Historical GIS demonstrate the spatial process underlying settlement evolution and visualisation of the spatial extent of the city during different periods from the locations of historical structures and buildings.
2. The land use and land cover mapping and change analysis has identified considerable fluctuations in LULC during the 1972 to 2018 period.
3. It was found that the built-up area has increased by more than 500% from 2100 ha in 1972 to 11984 Ha in 2020.
4. Further characterisation of urban expansion modes reveals dominance of infill and edge-growth type over leapfrogging as the growth of the city was rather compact resulting in intensive growth near the CBD.
5. The goodness of the urban growth index has found that the nature of urban growth was largely unsustainable in the city.
6. The spatial pattern of built-up patches suggests intensive built-up aggregation near the centre of the city and built-up fragmentation along the fringe through spatial metrics. The Largest Patch Index (LPI) suggests the evolution of new centres of urban growth in the rural fringe area surrounding the city which is becoming a new trend of urban growth in the study area.
7. The analysis of the nature of contemporary analysis through geospatial techniques identifies in-situ urbanisation and thus spontaneous rural-urban transition in the rural fringe of the study area.
8. Further, the study compares the urban dynamics of census towns and statutory towns in Mangalore taluk and establishes that the census towns were in many aspects are same or even better than statutory towns in terms of population growth and share of the population in non-agricultural activities. Still, the CTs and emerging urban centres of rural hinterland in the study area lacks infrastructure development.
9. The CA-based SLEUTH urban growth model has predicted a substantial increase in a built-up area in the study area for the year 2031.

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2. **Dhanaraj, K.**, and D. P, Angadi (2020) A GIS based interpretation of the historical evolution of urban settlements in Mangalore City, India. Spat. Inf. Res., Springer Singapore. https://doi.org/10.1007/s41324-020-00363-5.
3. **Dhanaraj, K.**, and D. P, Angadi (2021) '**Urban expansion quantification from remote sensing data for sustainable land-use planning in Mangaluru, India'**, Remote Sensing Applications: Society and Environment, Elsevier Publications, Volume23, August 2021. https://doi.org/10.1016/j.rsase.2021.100602.

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5. **Dhanaraj, K.,** and D. P, Angadi (2021) 'A geospatial enquiry into the nature of contemporary urbanisation in a medium-sized city of Mangaluru, India', Preprint, May 2021. https://doi.org/10.21203/rs.3.rs-465484/v1.

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Paper Presented in Conferences

1. **Morphometric characterization of Kumaradhara River basin in coastal Karnataka: A GIS perspective.** International Conference on urbanization, health & well-being and sustainable development goals, March 17-19, 2017, Dept. of Geography, Osmania University, Hyderabad, Telangana.
2. **"A GIS based interpretation of the historical evolution of urban settlement in Mangaluru city, India".** XIII International Geographical Union (IGU)-India, International conference on Heading toward zero: Sustainable development in Economy, Environment and Society" - October 19-21, 2019, Central University of Haryana.
3. "**Quantification of the Spatio-Temporal Dynamics of Urban Expansion Modes and Intensities for Sustainable Land Use Planning in Mangaluru, India**". National Web Conference on 'Environment, Development, and

Livelihood: Sustaining Earth and People', June 10-12, 2021, Department of Geography, Savitribai Phule Pune University, Pune and Institute of Indian Geographers.

4. **"Spatio-temporal pattern of land use land cover changes and urban growth detection from remotely sensed data in a medium-sized city of Mangaluru, India".** The IGS-International E-Conference on "EARTH SCIENCES AND SUSTAINABLE DEVELOPMENT GOALS", August 5-7, 2021 2021, Dept. of Geography, Osmania University, Hyderabad, Telangana in Collaboration with the Indian Geographical Society, Chennai.
5. ***Urban growth analysis and prediction using CA-based SLEUTH urban growth model in an emergent metropolis of Mangaluru, India'"***. 42nd IIG Annual Meet 2021 and International E-Conference on 'Geography for People, Planet, Prosperity and Peace, October 04-06, 2021, Dept. of Geography, Savitribai Phule Pune University, Pune and **Institute of Indian Geographers.**
6. ***"Geospatial Analysis and Visualization of Contemporary Urbanization and Rural-Urban Transition in Mangaluru, India"***. 43rd Indian Geography Conference on "Population, Environment, Health, Sustainable Development Goals and Appropriate Technologies: Post-Covid-19 Scenarios, October 28-30, 2021, Dept. of Geography, Benaras Hindu University, Varanasi, UP and **National Association of Geographers India.**

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